MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2016/2017

ENT4066 – NANOELECTRONIC MATERIALS AND DEVICES

(NE)

19 OCTOBER 2016
09:00 a.m. - 11:00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 4 pages with 4 Questions only.
2. Attempt **ALL FOUR** questions. The distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

QUESTION 1

(a) The magnetic properties of nanoparticles depend on the size, shape, and composition. With the aid of the diagram of *coercivity* as a function of *particle size*, discuss the size effect in ferromagnetic nanoparticles.

[3+4 marks]

(b) Sketch suitable figure and explain the theory behind the tunable optical properties of plasmonic metal nanoparticles.

[2+4 marks]

(c) A square parallel-plate nanocapacitor has a capacitance of 5 aF. The side length of the square plate is denoted as L, and the separation distance between the plates, d, is $L/15$. Answer the following:

(i) Determine the applied voltage, V, where Coulomb blockade occurs.

[2 marks]

(ii) Determine the temperature, T, for Coulomb blockade to be observed.

[2 marks]

(iii) Given that the permittivity, ε, of the material separating the plates is 8.85×10^{-12} $F{\cdot}m^{-1}$, determine both the length, L, and the separation distance, d.

[2 marks]

(d) Draw suitable diagram and explain briefly the classical theory (LaMer model) for the formation of monodisperse nanoparticles through separation of nucleation and growth.

[3+3 marks]

QUESTION 2

(a) Both (10, 8) and (13, 7) single-wall carbon nanotubes (SWCNTs) were obtained by seamlessly rolling up the graphene sheets along their wrapping vector directions. Answer the following:

(i) Given that the carbon-carbon (C-C) bond length is 0.142 nm, determine the diameter of both CNTs.

[2 marks]

(ii) Determine the chiral angle of both CNTs.

[2 marks]

(iii) Determine the chirality and conductivity of both CNTs.

[2 marks]

Continued...

(b) Compare the physical properties of CNTs as in the following:

- Current density with copper,
- Thermal conductivity with copper,
- Young modulus with steel.

[6 marks]

(c) What are the types of bonding found in graphene? Explain how these bonding affect its properties.

[2+3 marks]

(d) (i) With the aid of suitable diagrams, discuss briefly the ambipolar electric field effect in single-layer graphene.

[3+2 marks]

(ii) Propose **TWO** methods which allow switching the current in graphene on/off efficiently for digital logic applications.

[3 marks]

QUESTION 3

(a) Differentiate the scaling rules for the *constant electric field scaling* and *generalized scaling* of metal-oxide-semiconductor field-effect transistor (MOSFET).

[4 marks]

(b) Discuss the *challenges* and possible *solutions* of nanoscale complementary metal-oxide-semiconductor (CMOS) in the following contexts:

- Gate oxide thickness
- Junction depth

[8 marks]

(c) (i) Explain what electrostatic integrity (EI) of a device is.

[3 marks]

(ii) Using the ratio X_j/L_{el}, T_{dep}/L_{el} and T_{ox}/L_{el} for bulk planar MOSFET given in **Table Q3(c)**, calculate the EI value.

[2 marks]

(iii) Given that the built-in potential, φ_d, is 1 V, estimate the short channel effect (SCE).

[1.5 marks]

(iv) Given that the drain-source voltage, V_{ds}, is 1.2 V, estimate the drain-induced barrier lowering (DIBL).

[1.5 marks]

Continued...

Table Q3(c)

Ratio	Value
X_j/L_{el}	1/2
T_{dep}/L_{el}	1/2
T_{ox}/L_{el}	1/27

(X_j is the junction depth, L_{el} is the electrical channel length, T_{dep} is the depletion depth in the channel, T_{ox} is the electrical gate oxide thickness)

(d) (i) Sketch the basic structure of a planar double-gate field-effect transistor (DG-FET).

[2 marks]

(ii) Discuss briefly **THREE** advantages of DG-FET over the conventional single-gate FET (SG-FET).

[3 marks]

QUESTION 4

(a) (i) Sketch the current-voltage (*I-V*) characteristics of resonant tunneling diode (RTD).

[2 marks]

(ii) With the aid of suitable diagrams, explain the operating principles of RTD.

[3+4 marks]

(iii) Evaluate the performances of RTD integrated with complementary metal-oxide-semiconductor (CMOS).

[3 marks]

(b) (i) Sketch the energy band diagrams of single electron transistor (SET) illustrating the *Coulomb blockade regime* and *electron tunneling regime*, respectively.

[3 marks]

(ii) Based on the diagrams answered in **Q4(b)(i)** explain the operating principles of SET.

[4 marks]

(c) (i) Explain briefly the layer structure of a quantum dot laser (QDL).

[3 marks]

(ii) Evaluate the thermal stability of QDL in the contexts of *threshold current*, *lasing wavelength*, and *optical output power*, respectively.

[3 marks]

End of Paper